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ABSTRACT

This article provides a historical survey of computing in academe from scientific- and engineering-oriented batch computing through contemporary student use of personal computers in a wide range of disciplines. The transition from batch-style, through timesharing, to distributed computing using stand-alone microcomputers in conjunction with institutional networks is illustrated, as is the multi-faceted personality of the personal computer. Considerations accompanying the shift from timesharing to personal computing as the principal mode of computing are discussed, with emphasis on such issues as the financial burden encumbered by students, computer literacy, and software acquisition and dissemination. A sampling of institutional strategies for providing computing are related and the distinctive computing environments at several major institutions are explored in terms of physical, logistical, and pedagogical considerations. The trend toward corporate-institutional partnerships is accorded particular attention. The article concludes by recording thoughts on the pedagogical value of the personal computer from several sectors, including faculty, administration, and the computer industry, and attempting to establish a perspective for viewing the personal computer in the context of the total academic environment. (Author/THC)

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

A succession of rapid courtships finds several institutions of higher learning betrothed to one or another manufacturer of personal computers. Whether this introduction of machine genes will bring about fundamental changes in the progeny of such institutions—the clutches of learned youth they have spawned for more than eight centuries—will be determined, to some extent, by whether contemporary educators use computers or defer to them, on whether they promote . . .

Learning from the technology or learning with it: being a brief history of, and inquiry into, the presence of computers on campuses

Take an apple to my teacher? But my teacher *is* an Apple. A cute remark, perhaps, this, but one which represents, to some ways of thinking, the worst possible case in the computers in education scenario.

Computer lineage

From antiquity (that is, approximately forty years ago), computers have served up facts and figures to those who input the requisite data. They have variously supplied solutions to complex equations; calculated means, averages, and percentiles for rows and columns of raw statistical data; printed pages upon pages of employee salary and benefit information for institutional administrations. Scientists, researchers, and administrative officials have learned from this material. The numbers they derive perhaps replace variables in yet other equations, or lend numerical support to theses presented in social science journals, or validate an institution's employee payroll. In all cases, a computer has proffered output from some set of input.

The distinction being pursued is subtle; the nature of learning *with* an instructor, *with* a fellow student, even *with* the printed works of a great thinker, is substantively different from what most often takes place with a computer. One can learn with the aid or help of a computer, but that is not the same thing as learning *with* it. The difference may not be reducible to anything more than the experience of thinking in the presence of another being, or some residue of one, that thinks, or thought, like one.

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Most educational applications developed for computers to date have followed the input/output paradigm; they have been characterized by fixed and predictable exchanges between students and machines. The worry associated with the simplistic portrayal in the opening paragraph has to do with the fact that, by and large, computers are still input/output-oriented machines, machines that one can, in a way that is more than less rigid and formalized, learn *from*. Contemporary computers, even those that incorporate elaborate configurations of parallel processors and are imbued with artificial intelligence of the highest sort, cannot create, empathize, intuit, or sense in any way related to the cognitive or emotional makeup of students. Indeed, one does learn *from* a human instructor, but one also, in ways that do not lend themselves to existing modes of quantification, learns *with* her or him.

The foregoing exercise in semantics is intended only to affirm that educational applications of computers are, as yet, bounded, not to diminish the value of what has been learned from computers. Business, government, industry, science, and society have, to varying degrees and in ways that range from subtle to revolutionary, changed

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as a result of knowledge gained from what has poured from the "mouths" of computers over the course of the past few decades.

To extrapolate a solution, however popular and cheap, to a problem that might be of a fundamentally different nature, entails a risk, not alone that the solution might prove ineffective, but that its attempted implementation might aggravate the problem. The computer has not slighted education; institutional research and administration were among its early benefactors. Nor was instruction slighted, although benefits thereto have been, to a great extent, discipline-specific. At risk in positing the computer—because it has proved efficacious in so many applications and is now cheap enough for individual ownership—as a general solution to myriad and long-standing problems associated with formalized education, is not alone the failure of the proposed solution, but the possible confounding of a process that is at best little understood.

Today's liaisons between educational institutions and computer manufacturers are brought about by the arrows of more than one Cupid; amid the flurry are shafts loosed by the Cupids of capital gain and institutional peer pressure, as well as by the Cupid of educational enhancement.

Because education at the primary and secondary levels is largely public and mandated, its purveyors are not obliged to recruit their charges. At the post-secondary level, however, the economic vitality of institutions in the business of providing education can be significantly affected by competition for students. Educational benefits need not be substantiated, but only perceived, to render the incorporation of computers into an institution's educational strategy an economically sound move. If students, and those who pay their tuition, are affected as intended by the messages being promulgated by manufacturers—that computers can provide an educational advantage—colleges that, for reasons financial or otherwise, do not elect to be washed by this wave could find their admissions declining as students gravitate toward institutions whose shores it has strewn with the flotsam and jetsam of technology. That the messages are having the intended effect is evident in the increasing familiarity of elementary and high school students with computers, either purchased for them, at no trifling expense, by their parents, or made available by their schools through grants, taxes, or the fund-raising efforts of parents who do not want to place their children at risk by doubting the touted educational virtues of the machines.

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Computers are not new to schools. As early as the 1950s, researchers at colleges and universities were using computers, at other institutions if their own did not possess one, to support scientific inquiries in such fields as chemistry, engineering, and mathematics. Then the computer was, like the electron microscope, an expensive and limited-application tool of research. Computing capability, because the equipment that delivered it was enormously expensive, was usually provided centrally and the expense shared among the departments and operating units that used it.

Generalization of the computer's utility beyond that of a high-speed solver of complex equations turned on its programmability; if different equations could be solved by writing different programs, then by writing yet other programs the computer could be applied to other numerically-based activities. With the birth of electronic data processing, the computer became a tool not only of accounting departments of businesses and corporations, but also of college and university administrations. Without forsaking its utility as a computational device, the computer entered the 1960s as a general-purpose "information processor".

The principal academic users of computers at this time were students in college engineering courses, who would keypunch computer programs into cards, drop them off at the campus computing center to be processed, along with dozens of other programs, on the institutional computer, and later pick them up together with pages of fan-folded, continuous-forms paper on which were printed the results of their programming efforts. This mode of interaction with a computer is termed *batch processing*.

Occurring during a period of heightened anxiety about the potential automation of much human endeavour and the reduction of human beings to numbers for purposes of storing and processing information about them, the nominal penetration of the campus by the computer in the early 1960s was protested by students at a number of universities, even to the point of bombing a number of computer rooms. Philosophical objections to the new technology, however, were gradually eroded by the computer's incredible efficiency coupled with an increased accessibility that served to diminish its apparent threat.

The earliest manifestation of decentralization, that is, putting the computer resource in the hands of its users, took the form of remote, self-service card readers. It was of the nature of a baby step compared to the reorientation, in the mid-1960s, around timeshared computing, by which many individuals are afforded simultaneous use of a centrally-located *mainframe*, or high-capacity computer, sans punched cards, by communicating with it interactively through remote, typewriter-like computer terminals.

These developments were enabled and supported by the increasing sophistication of computer *operating systems*, complex sets of programs that enable a computer to handle much of the low-level detail of its operation. An operating system, one

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or more *compilers* (e.g., FORTRAN, COBOL, etc.), and a number of *utilities* (i.e., programs for automating general tasks, such as sorting and copying of files) were usually bundled with computers sold during this time. Additional *applications* software (programs for automating specific tasks, such as solving scientific equations or processing accounting or payroll data) was available separately, either from computer manufacturers or from one of a growing number of "software houses" (firms that specialize in writing and marketing applications software for a variety of common applications). Fed by the latter, the base of applications software expanded rapidly leading, by the late 1960s, to litigation against computer manufacturers that resulted in the unbundling of computers and software.

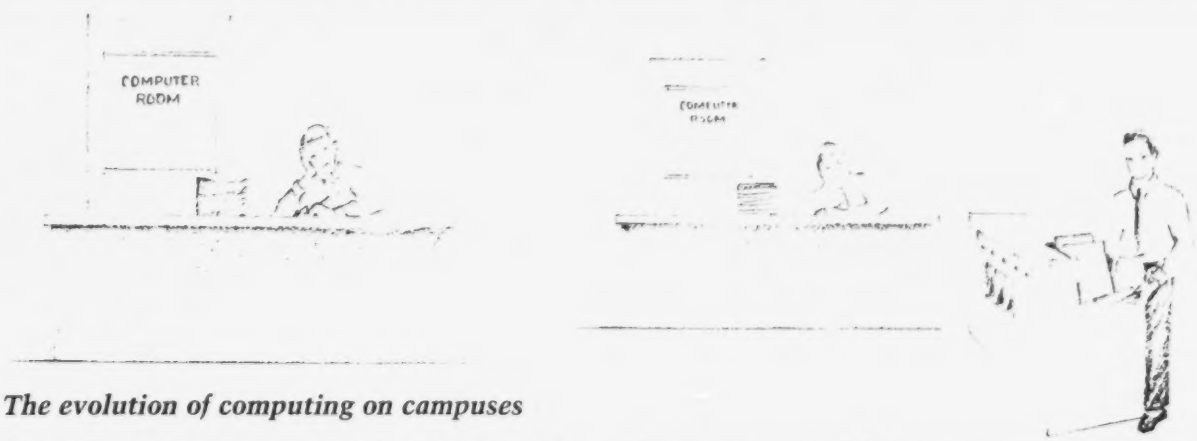
Successive generations of computers, each with capabilities manyfold greater than their immediate predecessors, held promise for automating more and more scientific and administrative activities, and programming blossomed as the profession through which the creation of the requisite applications programs was realized. From a time in the very early evolutionary stirrings of computers, when some among those associated with their development were led to speculate that a dozen or so machines would saturate the world market, it had become exceedingly apparent that computers were destined to proliferate far beyond such expectations. Fields of study associated with the further understanding and application of computers melded into a new discipline—computer science. Its subject matter consisted of such elements as: computer architecture (the study of the application and performance of computer systems from the perspective of their underlying structure); numerical methods, (the mathematical substantiation of the computational approaches used in computing); and artificial intelligence, (the realization of characteristics usually associated with human intelligence—such as language comprehension, problem-solving, learning, and reasoning—in machines).

By the end of the 1960s, library ordering systems, statistical packages, and collections of routines for solving sets of complex equations in chemistry, engineering, and other sciences had joined the manifold applications that programmers were employed in the creation, maintenance, and refinement of. Text processing, a mainframe-based version and antecedent of word processing, had begun to elicit interest in the capabilities of central computers in non-traditional quarters. During the 1970s, the numbers of adventuresome faculty in college and university liberal arts departments petitioning their computing centers for computer terminals and timesharing accounts increased significantly.

For fully two decades, the provision of computing was marked by an ebb and flow of such issues as centralization versus decentralization, and consolidation versus separation, of academic and administrative computing facilities, and by debates over whether computing should be provided in the library tradition, as a "free" service, or charged back as in the bookstore model, either directly to students in the manner of lab fees, or to the academic departments offering courses that make use of the computer.

In general, computing centers encouraged diversified use of their equipment. As the further sophistication of operating systems, applications programs, and computer terminals combined to make connected mainframe computers more tractable, the number of users multiplied.

Although their designation as "mainframes" gave central computers



The evolution of computing on campuses

In the beginning, computing was done behind closed doors. Those who wanted information from a computer or had problems for it to solve generally got no closer than a person at a counter who carried their problems or requests, as they had keypunched them into cards, into the computer room.

Remote computing establishes access points to a central computer outside of the room that contains it. Common by the late 1960s were remote card readers that enabled users to read their own cards into computers that were located elsewhere, cabled to the readers from other rooms or even other buildings.

an aura of unlimited capacity, in fact, there were limits, reached with increasing frequency over time, to how much processing such computers could handle. Considerations relative to making significant upgrades to equipment in-place and/or seeking replacement machines of still more behemoth proportions, became standard fare for computing center administrators. It was at this juncture that academic and administrative computing, at those institutions where they had grown up together, often parted company, with a new machine being acquired for one or the other, thereby reducing the load on the extant computer. Meanwhile, decentralization had rounded another corner with the advent of minicomputers, relatively modestly-priced, modest-capacity systems that enabled some departments to satisfy their computing requirements independently of the institutional computing center.

Yet, for all their increasing presence, and increasing drain on institutional budgets, computers contributed little to the mainstream academic mission of colleges and universities. Not that the idea that computers could be used to teach had not occurred to anyone. Plato, a computer-based teaching system developed at the University of Illinois and marketed by Control Data Corporation, was in use in the very early 1960s but, in part because it relied on expensive, special-purpose equipment and employed a complex authoring language for development of programmed instruction, it never became the widespread teaching phenomenon that some had forecast.

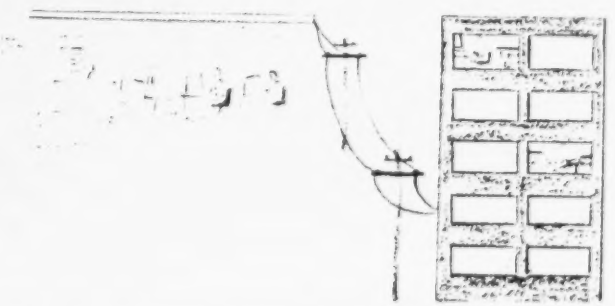
In the mid-1960s, there was a reorientation around timeshared computing, by which many individuals are afforded simultaneous use of a centrally-located mainframe, or high-capacity computer, sans punched cards, by communicating with it interactively through remote, typewriter-like computer terminals.

With computerized instruction more or less a laboratory activity, the computer of the 1960s and early 1970s, despite its increasing costs and use, and though indispensable for what it did, was to the administration little more than an automated set of books and files; to the scientific and research communities, an impressive calculator; to the computer science curriculum, the object of a course of study; and to the rest of the academic community that availed itself of it, a replacement for the venerable typewriter.

Those who argued for free, or "open", access to the computer chose a good analogy in the library. As traditionally employed by academics at colleges and universities, the computer, like the library, has been an important and useful adjunct to the educational mission. Like the library, it has been "over there", a place one goes on occasion when an assignment warrants. Also like the library, it has been both more intimidating to some students than to others, and more useful to some than to others. As some students have successfully completed college without ever visiting the library, so today, students graduate without ever tapping on the keyboard of a terminal or a personal computer.

There is another aspect of the library analogy that is germane. In an era in which an "information explosion" is said to be taking place, libraries are hard-pressed to keep pace because of physical and logistical constraints. So, too, as latent demand for each new application of the computer surfaced, capacity was quickly exhausted. Getting time on timeshared computers became a major frustration for all concerned. Faculty who could do without the computer often did; those who wanted or needed access to it for their students either limited the amount of work that required such access or pressed for priority use for their students, and computing center administrators became computing center arbitrators, whose time not spent mediating among committees variously representing the interests of the academic, administrative, and research communities (for which, it was becoming apparent, there could

Card decks are queued, or batched by a computer and processed sequentially as a series of jobs. By contrast, timesharing, which began to appear in the late 1960s and early 1970s, allowed multiple users operating typewriter-like terminals to interact seemingly simultaneously with a central computer. At first, terminals were cabled directly to computers and batch and timesharing processing was usually done alternately. Later computers handled both kinds of processing simultaneously, and the development of modems and other telecommunications devices enabled terminals to be located anywhere they could access telephone lines.



With the proliferation of micro, or personal, computers, in the 1980s, computing retreated back into the computer room, but the computer room can now be a dormitory room, a bedroom, even an ample closet. Miniaturization of the computer and its quarters notwithstanding, much of what has gone before remains. At many institutions, strategies for taking central computing facilities into the personal computing era are being formulated within earshot of the hum and drone of traditional computer room sounds, occasionally punctuated, even yet, by the primal chatter of a card reader.

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Although their designation as mainframes *gave central computers an aura of unlimited capacity, in fact, there were limits, reached with increasing frequency over time, to how much processing such computers could handle.*

never be enough computer resources) was devoted to plying their systems programmers for creative new ways to divide and prioritize available resources and to negotiating with their institutional administrations for funds for more of the same.

That some small part of the overburden bringing timesharing computers to their collective knees around the late 1970s and early 1980s was relief for libraries is another story (told, in part, in the Spring 1985 issue of this newsletter); relief for the timesharing computer operated by the campus computing facility came from within its own cadre—the microcomputer that had been a project of electrical engineering students and a toy of home electronics enthusiasts during the early 1970s came of age just in time to allay the woes of its precursor.

A computer in every dormitory room?

Although year by year, micro, or personal, computers have grown increasingly powerful (that is, have become capable of processing more information faster, and storing it in ever greater quantities), their principal application in the educational environment has been, and continues to be, in writing, or, as reduced to its computational equivalent by the computer community, "word processing". It is a matter of curiosity that this application, one of but a few whose educational value shows some promise of being demonstrable, fell into disfavor when things got tight on central timesharing computers; some computing centers considered word processing non-essential work and severely restricted, or even totally banned, it during periods of peak use.

Personal computers have put this application, along with a number of others, including instructional computer programming, into the hands of individual students. To the extent that a school's students have, or have access to, personal computers, the pressure on computing centers to make value judgements regarding the legitimacy or relative worth of applications on their timesharing computers is reduced. Instead, such centers can get on with the business of their own further evolution, for the personal computer, despite its amazingly rapid proliferation, is not the be-all and end-all of computing. There are still many tasks that require machines of the proportions of contemporary mainframes; indeed, there are computationally complex research tasks for which even mainframes must defer to a class of machine that is larger still, the scarce—but equally essential for what it does—supercomputer.

Relief for the timesharing computer operated by the campus computing facility came from within its own cadre— the microcomputer came of age just in time to allay the woes of its precursor.

Even as personal computers relieve their larger siblings of some of the routine tasks for which users have traditionally been required to contend, they make other, and often novel, demands not only on central computers but on the support staffs of the computing centers that operate them. Both centralized storage for purposes of backing up microcomputer-resident data, and file service for distributing and collecting assignment-related data for academic courses, require networking capability significantly more sophisticated and reliable than is called for to support hosts of timesharing computer terminals. Many users of personal computers, being former, and perhaps still occasional, timesharing users turn quite naturally to computing center staff for help with, and advice on, personal computer-related matters. Their abetting influence notwithstanding, personal computers are engendering service and support needs that many computing centers are finding they cannot meet with existing resources and within existing budgets.

The potential pervasiveness of the personal computer derives directly from its self sufficiency. Computer terminals could not have effected so wholesale an occupation of student dormitories as personal computers have on some campuses because of limitations in the number of *ports*, or points of entry, on central timesharing computers; the number of simultaneous users that even the largest such systems can support is in the low hundreds. Although most personal computers can be used as terminals into timesharing computers, such use is ancillary to their ability to function as stand-alone computers.

Although personal computers haven't the full power of contemporary timesharing computers, because most students can do on them most everything they would have occasion to do on an institutional machine, the personal computer creates a potential for doing what was just a few years ago unimagineable—providing each student with not only access to a computer, but the computer itself.

Personal computers have become as affordable as good second-hand cars or first-rate stereo systems. But just as cars and stereo systems are not in every college student's budget, so neither might a several thousand dollar personal computer be. Schools are helping; in addition to procuring discounted computers for students, some are taking computer purchases into consideration when assembling financial aid packages. Others are helping students to arrange for low-interest loans from outside lending institutions. It is fitting that they do so; a computer purchase is overburden for a student, not fill for an expense that has been eliminated. Students are still required to buy books, to pay laboratory fees, etc. Now, additionally, they are being asked to subsidize the cost of providing computing from which, admittedly, they are expected to derive some educational benefit.

Notwithstanding that a machine equivalent in capability to what an

institution might have struggled to pay for a decade ago is now affordable by an individual, the total cost of providing institutional computing has gone up. The plummeting cost of hardware has been offset by the rising cost of software development and a vastly increased use of computers, and sellers, as well as buyers, of the machines are being driven to some creative reassessments. Having successfully put its computer on a sliver of silicon and packaged it in a box that can sell for several thousand, instead of several hundred thousand, dollars a manufacturer finds that time becomes an expensive commodity; unlike mainframes, which can warrant weeks, or even months, of sales effort, personal computers can be afforded only minutes if their sale is to yield a profit.

If a high volume of sales can be generated by conceding substantial discounts in that few minutes, because the resulting penetration might help a vendor to establish itself in the educational marketplace and breed loyalty for its products in the students who use them, the vendor might exchange a short term loss for longer-term profitability. The institution that negotiates such a discount is coping with the rising cost of providing computing by reducing the cost of doing so if it makes the machines available directly, and by redeploying some of the expense if it resells them to students.

The ultimate cost of promoting the proliferation of personal computers, and of providing the centralized services, underlying network facility, and logistical and human support necessitated by their proliferation, will not be known for some time. For now, it is generally considered that personal computers are affordable by students, and that students should be encouraged to acquire them. Indeed, many who arrive at college today bring with them personal computers acquired while they were in high school.

But though it be capable of putting into the hands of each student all of the capability that most ever demand from a timesharing computer, in a package that is much easier to use and far more available, will the personal computer revolutionize education? We noted earlier that the most frequently used application of personal computers is word processing. Have we simply altered our earlier analogy, substituted for the lofty library the utilitarian typewriter and correspondingly denigrated the value of the proliferating personal computer?

As a writing "medium"—and that, to date, has been its most widespread academic application—the personal computer has many advantages over traditional implements of the craft. Software has been developed that can analyze grammar and sentence structure and advise writers of potentially awkward or inappropriate constructions, that can perform word counts that might alert writers to overused words, and that can proffer substitutes for multi-syllabic and compound words. Such software lends a faint lumination to the horizon. It is not, however, the software being used by the great multitudes of personal computer users; theirs is a conventional, and far more rudimentary, kind of word processing software that is as darkness to it. A glorious dawn is portended but, withal, the use of the computer to *teach* writing must, like every other application of the computer to the teaching of complex subject matter, await significant further developments in the field of artificial intelligence.

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For the present, as applied to writing, the personal computer is at best a great facilitator. By eliminating the need to retype the bulk of altered text, it reduces resistance to revision. Resistance overcome, the writer finds in personal computer word processing software the greatest boon to revision since scissors and tape. Without affecting the original manuscript, an author can effect everything from a subtle refinement of a single sentence to a wholesale reorganization of a lengthy text by rearranging the transitory images—of words, sentences, paragraphs—on a video display screen. The author can then read the reordered material through, alter it further if desired, and repeat the process ad infinitum, all the while preserving the original intact. Although one can make a xerographic copy of a typed or handwritten manuscript handily enough, in the cutting apart and rearranging of it, scissors work one's hand much harder at the word and sentence levels, and tape becomes increasingly intractable with each iteration. Further, with a typewriter one must sit down at the machine, set margins, tabs, etc., and then commence hammering away at the keys to effect the transformation from draft to finished manuscript (or pay someone to do it for one). A word processor, given access to a compact, electronic version of a draft manuscript, needs only to be instructed as to the parameters of the final format—margins, lines per page, etc.—into which it will flow the copy like so much gelatin into a mold. This, too, it will do over and over again, to varying specifications and the ultimate satisfaction of the writer. In addition, most contemporary word processing packages are provided with a *dictionary* (computer vendor vernacular for "word list") against which it can compare the words in a manuscript for the purpose of checking spelling.

Does such utility make students better writers? Certainly, there is no inspirational component to word processing software. It cannot comment upon the meaning that derives from the arrangement and rearrangement of words that it so ably facilitates, nor can it discourse on the nature of the art of writing. The making of a writer is still a thing that is achieved by an individual, perhaps with the guidance and encouragement of another individual. For the present, the virtue of word processing has to do with the mechanical aspects of writing, with the physical acts of writing or typing, revising and reorganizing, formatting and reformatting. A blank video display screen is no more

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inspiring, and every bit as intimidating as a blank piece of paper in a typewriter or under a pencil or a pen. Word processing cannot make a student a better writer but it can make it easier for a student to become a better writer.

Such utility might be worthy, but it is not the stuff of which marriages between institutions of higher learning and major corporations, some attended by multi-million dollar dowries, are made. There must be, and, in fact, are, greater expectations for the role of the computer in higher education.

Such expectations are held by colleges and universities that have established institution-wide computer literacy requirements, as fifteen thousand student Southwestern Michigan University and thirteen hundred student Alverno College in Wisconsin have, by schools that have instituted curricular changes that have led them to require, or strongly encourage, every incoming student to purchase a recommended personal computer as the Stevens Institute of Technology in New Jersey, and the Harvard Graduate School of Business Administration have, and by institutions that have allied themselves with one or more of the major manufacturers of personal computers in cooperative ventures involving very large sums of money and significant commitments of corporate and institutional staff and resources, as Brown University in Rhode Island, Carnegie-Mellon University in Pennsylvania, and the Massachusetts Institute of Technology have.

These schools are merely representative of a widespread perception among institutions of higher learning that the role of computer-related technology in education is going to become increasingly important and fundamental. When college administrators talk about computer technology and tomorrow's students they are referring, quite literally, to the students who will be enrolling tomorrow; the students who enrolled yesterday are the guinea pigs of today's technology. The situation reflects, quite simply, the fast pace of development in the computer industry.

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Taking advantage of the baby computer boom

The investments that educational institutions are today making in computing are, to a large extent, proportional to their historical investments in computing. Those institutions that strove to provide the greatest base of computer hardware and to encourage the broadest possible access to it were the ones most often beleageured by demand; major upgrades and banks of additional disk drives and terminals spelled mainframe timesharing computers for as much as a year or two at first, then for but a few months. Institutions coped with saturation of computing facilities, which was a way of life at many of them before the microcomputer was even a gleam in an engineer's eye, by periodically infusing large sums of money into equipment upgrades, by scheduling or restricting access, by charging back rigorously for use, or by some combination of these approaches. That these same institutions, when it came of age, should have sought succor from the personal computer is not surprising.

Dartmouth College in Hanover, New Hampshire, is one institution that did so. Dartmouth's tack through the choppy seas of personal computing is altered little from that which has borne it across the undulating swells of timesharing. Albeit slight, the alteration—which has to do primarily with cables and the nature of the traffic through, and phycical connections to, them—is significant.

A pioneer in providing timeshared computing, and of the library parallel of "free", or "open access", Dartmouth began to feel the hard pinches of space and dollars several years ago. The problems have been alluded to earlier: demand was exceeding capacity; space in which to locate additional terminals, which would increase the load upon, and necessitate upgrades to, the College's mainframe, was wanting; the costs of the upgrades, terminals, and space were becoming prohibitive. With a long tradition of timesharing, and with attendant miles of wire and cable that had snaked through the campus, Dartmouth was already a largely "wired" college.

Recognizing that the evolving personal computer would soon overtake timesharing as the unquestionably most effective means for providing academic computing, Dartmouth decided, a couple of years ago, to make intentional the inevitable crossover.

Among the centrally-supported services that have been available to users of Dartmouth's timesharing system are an on-line catalog of the holdings of the College library and an electronic mail system. Access to these resources would have to be preserved in any extensive shift from timesharing to personal computing. This could be accomplished by ensuring that students' personal computers possessed the ability to function as terminals into the timesharing system and by providing the necessary network connection to enable them to do so. Dartmouth considered its institutional role in precipitating the shift from timesharing to personal computing to be to identify considerations such as distinctions between centrally- and locally-supportable services; to retain responsibility for maintaining, enhancing, and increasing access to,

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Timesharing vs...

Once upon a timesharing paradigm, computers were sliced up like great pies and those who wanted a piece of one queued up for it. Networks, like kitchen tables, were utilitarian things intended to accommodate only as many people as there were pieces of computer pie.

the former; and to make recommendations regarding appropriate complements of equipment for the latter. The College's first conclusion was that a student-owned computer should possess: 1) sufficient capability to do locally much of what can be done on its timeshared computers, and 2) the ability to communicate as a terminal to do the rest. Expectations for a machine's local capabilities included word processing, graphics, and BASIC-language programming, and its remote capabilities, personal computer-to-personal computer and personal computer-to-timesharing computer communications.

Recognizing that the evolving personal computer would soon overtake timesharing as the unquestionably most effective means for providing academic computing, Dartmouth College decided to make intentional the inevitable crossover.

Precursor to the widespread introduction of personal computers at Dartmouth was a small-scale introduction of International Business Machines Corporation (IBM) PC personal computers to the Amos Tuck School of Business Administration, which already had a bank of teaching materials on the Dartmouth timesharing system used by all first year, and some second year, students. Although no purchase requirement was established when the PCs were introduced, approximately forty percent of incoming Business School students acquired one. Subsequently, on the College's recommendation, approximately eighty percent of Dartmouth's incoming freshmen acquired a Macintosh personal computer.

For its part, the College commissioned the writing of software that would enable the Macintosh to be operated as a terminal into the timesharing system (the Macterminal software was not yet available) and undertook to extend the wiring of the campus, which already ran to almost every academic and administrative office, into the dormitory buildings with a network tap per desk or bed, as the case might be. To achieve the wide range of personal computer-to-personal computer and personal computer-to-timesharing computer communications it considers necessary, Dartmouth has implemented a variety of networking protocols, including asynchronous, Appletalk, X.25, and Ethernet. The College's long experience with computing is perhaps responsible for the exceedingly practical, albeit informal, projection by William Arms, former Vice Provost for Computing and Planning at Dartmouth and newly-appointed Vice President for Computing and Information Services at Carnegie-Mellon University, of the completion of the network, begun in 1978 and already operational, by the turn of the century. The flexibility being built into the network is a conscious hedge against the inevitable shifts and developments that can occur over so protracted a period.

...a distributed network

The coming of the personal computer afforded individuals an opportunity to have their own individual pies. This reduced demand on, but not the need for, great pies, leading many institutions to tack on extensions to their kitchen table networks, and others to build, or buy, banquet table networks that can seat entire institutional hosts, enabling those sharing great pies to sit down with those eating their own individual ones.

As we stand in awe of the tree of technology in all the glory of its spring—robust trunk and myriad leaf-laden branches glimmering in the equinoctial sunlight—our perspective can be easily impaired. By its dictionary definition, technology was spawned with the first application of science to the furtherance of some human endeavour. Its root system is extensive, and even if we look only at what is above the ground—what the scientific leaps and bounds of recent history have thrust up and spread over us—our gaze cannot be contained in the twentieth century. Institutionalized study of technology, for example, harkens back to the previous century. The year 1870 marks the founding of the Stevens Institute of Technology, one of the original private institutions devoted to the study of technology in the United States.

The Stevens curriculum having broadened, over its history, from mechanical engineering to include other engineering disciplines, science, management, and computer science, its early appropriation of, and growing reliance upon, computers is consonant with its institutional raison d'etre. That Stevens faculty had reached the conclusion that the use of computers in engineering was altering in a fundamental way engineering practice, was reflected in the adoption of a revised core curriculum in the late 1970s. Convinced that a new cognitive style for problem solving, analysis, and design in engineering was being engendered by increasing utilization of computers, but convinced as well that the curriculum could not accommodate additional courses to provide students with the requisite grounding in computers, Stevens engineering faculty moved to make computing an integral part of the engineering student's undergraduate experience.

Convinced that a new cognitive style for problem solving, analysis, and design in engineering was being engendered by increasing utilization of computers, Stevens Institute of Technology faculty moved to make computing an integral part of the engineering student's undergraduate experience.

The approach was intended to make computing pervasive and to beget in students a level of understanding and appreciation that Stevens termed computer "fluency". As distinguished from computer "literacy," in a paper by Edward A. Friedman and Joseph J. Moeller, Jr. "[The Stevens Personal Computer Plan", *EDUCOM® BULLETIN*, No. 3/4, Fall/Winter 1983, p.13], computer fluency has as its objective to impart to students the following attributes:

- a natural inclination to turn to the computer when appropriate and to interact comfortably with it;
- the ability to identify capabilities and limitations of computer systems and software;
- the ability to develop higher-level language programs for significant engineering problems;
- competence in implementing professional techniques, including numerical methods, modeling, simulation, computer graphics, data acquisition, and process control.

Because timesharing was still the predominant mechanism for delivering computing services when Stevens embarked on this course, its campaign to foster widespread computer fluency was promptly run aground by saturation of resources. At Stevens, as at so many other institutions that promoted academic computing, the all-too-consistent theme of utilization outstripping hardware expansion was played out. The Stevens response was a counterpoint that is increasingly being picked up by other institutions.

In making ownership of an Atari 800 personal computer with tape drive and television monitor requisite for the eighty students entering its Science, Management, and Computer Science programs in the fall of 1982, Stevens became the first college in the country to establish a personal computer requirement. The following year, extension of the requirement to the engineering program, with its need for a professional engineering workstation-equivalent, led to the Digital Equipment Corporation (DEC) Professional 325 being designated as the required machine.

In addition to negotiating special pricing for required computers, Stevens has further sought to keep student costs down by establishing a computer peripheral center which provides access to a handful of DEC Professional and Atari computers with attached printers and serves as a point of transfer for data, programs, and assignments from faculty to student floppy disks.

In ways both similar and different, the Milwaukee Area Technical College is providing another genre of education in technology[1]. Engaged in the training of technicians rather than professionals, the College recruits its student body from the ranks of those laid off by old-line industries and those who must adapt to retain their jobs in growing, and changing, companies, as well as from the graduating classes of high schools.

Like the Stevens Institute of Technology, the Milwaukee Area Technical College expects its students to derive substantive benefits from their interaction with the devices of technology. According to the latter, in contemporary industry:

> The greatest need is for the "super tech", who can install, operate, maintain, and repair systems that may incorporate combinations of electrical motors, digital circuits, mechanisms, hydraulic actuators, lenses, light sources, and transducers. Many of these systems are controlled by microcomputers and are part of huge computerized databases requiring persons skilled in information management, including documentation development, storage, retrieval, and decision making.

The College regards its mission to be to insure that persons with the requisite interdisciplinary skills and knowledge to serve this need emerge.

Unlike Stevens, the Milwaukee Area Technical College relies heavily on institutionally-owned equipment acquired largely through its aggressive pursuit of partnerships with area industries. Individual pieces of equipment supplied to the College by various of its industrial partners have ranged in value from one hundred thousand to more than one million dollars. In return for their beneficence,

[1] Information about the Milwaukee Area Technical College, including quoted material, was derived from Marc S. Tucker, ed., "Computers on Campus: Working Papers," *Current Issues in Higher Education*, [American Association of Higher Education, 1983-84, Number 2], 34-36.

representative technical employers from the industries are invited to participate in a steering committee charged with reviewing, and making recommendations on, the relevance of the College's curriculum and the effectiveness of the training it is delivering.

Industry observations constitute only a part of the College's broad evaluation scheme, which also includes specific measurements, as of the efficiency of student workstation scheduling, common assessments, as those made by faculty regarding improvements in the teaching of scientific and engineering principles, and reviews of bodies of data, ranging from annual enrollment statistics, through student achievement and course completion surveys, to follow-up surveys conducted post-employment.

Whether on a professional or a technical track, students of technology, in the course of their continuing relationship with it, can expect to have to use the devices of technology as well as understand them. The places that school such students most effectively will provide them with both theoretical comprehension and practical operational skills.

Whether on a professional or a technical track, students of technology, in the course of their continuing relationship with it, can expect to have to use the devices of technology as well as understand them. The places that school such students most effectively will provide them with both theoretical comprehension and practical operational skills, weighted according to the perceptions of their institutional missions. Thus, at the Stevens Institutes of Technology and Milwaukee Area Technical Colleges of this country, computers and other devices of our so-called hi-tech society are, to varying degrees, both a means and an end. At other institutions, in other disciplines, we can find computers employed in another way, as means to ends that are only tangentially, or not at all, related to the technology that occasioned them. Some samples, selected from many possible others, follow.

■ Observing that the availability of relatively inexpensive information processing has contributed to radical changes in economics over the past twenty or so years, Harold Cochrane, of Colorado State University, proposed to employ that agent as a partial remedy for textbooks that have not kept pace, that, according to Professor Cochrane, "portray the economy in an oversimplified and somewhat antiquated light"[2].

Using commercially available spreadsheet software, Professor Cochrane developed a series of exercises designed to commingle role-playing and interactive student participation in the comprehension of principles, and solution of problems, in economics. The exercises engage students in the building of models to solve problems posed to them as they variously play the roles of consumer, banker, bond-trader, and businessman. Students are introduced to the techniques with a simple consumer problem; for example, given a specified income, and a starting age, age at death, and a determination to retire at age sixty-five, students are asked to allocate their income so as to make ends meet. Often players are astounded to discover how a slight change in the inflation rate can throw off their calculations, leaving them millions of dollars in debt by the time of their demise. Later in the course, as heads of businesses, students might be asked to allocate labor in a simple production process, observing the effects on profitability of the varying sizes of the work force. The allocation of labor just up to the point where it pays off, a strategy well-known to commercial firms, comes as a revelation to many students, but one derived, Professor Cochrane observes, by the student themselves; and therein, he contends, is the value of the exercise. Among his objectives is the training of students as mechanics in the use of the logical and relatively straightforward tool that is electronic spreadsheet software. Experimenting with the tool in the context of the exercises, students come to an appreciation for how the frameworks of the spreadsheet and the economics problems they are trying to solve are connected. By building upon accummulated logic, they gradually become masters of their own models.

A macroeconomic model, built by Professor Cochrane, enables students to put together what they've learned in the process of constructing their own models to solve problems in each of the various roles they've played. Using this pre-constructed interactive version of a textbook model, students can vary parameters of the economy singly and in various combinations and observe the often complex and far-reaching effects of their changes.

The spreadsheet software, Professor Cochrane observes, releases students from the bondage of complex mathematics, freeing them to concentrate on the solution of problems and assimilation of principles. To prove a solution by means of calculus, he notes, might take a student two to three days, as opposed to five minutes using the spreadsheet. Additionally, spreadsheet models lend themselves to adaptation; to add inflation to a model that lacks that parameter, Professor Cochrane observes, is a task of but a few minutes.

As prelude to developing a complex, centrally-controlled interactive economics game, Professor Cochrane experimented with a somewhat more modest energy game which he found unwieldy. His experience led him to conclude that at present, at least in economics, such structures make it difficult to "get the lessons out on the table."

Professor Cochrane's experience with in-class use of personal computers has been that it both significantly slows the pace of the class and requires that he spend more time with each student than is available for an ordinary class. For the time being, Professor Cochrane believes, students are best served by using computers in their own possession, or, failing that, using machines provided for them by the institution in some sort of laboratory setting.

[2] Information about the work of Harold Cochrane was derived in part from Tucker, "Computers on Campus," 29-31, and from personal communication.

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■ Daniel Fivel's appropriation of the personal computer derived from a nagging concern about what he regarded as the "tortuous path" that students have to negotiate in order to arrive at an understanding of the subject matter of his field[3]. A member of the Department of Physics and Astronomy at the University of Maryland, Professor Fivel's field, characterized by rapid change and relatively little time to teach it in, is optics.

Optics is traditionally taught, according to Professor Fivel, as a chronological succession of models, each of which supercedes and renders obsolete its predecessor. Thus, students learn and unlearn two models in order to arrive at a third, contemporary model. Apparatus—sensitive detectors and strong light sources—exists by means of which students could apprehend the modern photon theory of light promptly, but it is extraordinarily expensive and dangerous if handled improperly. What Professor Fivel intends to contribute to the study of optics is a computer programmed simulation of the behaviour of light that will not only reveal its true nature to beginning students, but will also accommodate the manipulation of parameters that govern its behaviour over a broader range to produce effects that would be unattainable even with the most expensive apparatus. The simulation program, which is being developed on an Atari 800 personal computer, is indicative of the potential of the computer to affect not only teaching methods, but course content as well.

■ Around 1980, Donald Thursh, at the University of Illinois College of Medicine, initiated a project aimed at breathing life into a textbook of pathology[4]. Dr. Thursh's earliest work on The Living Textbook of Pathology was carried out on a mainframe computer using the PLATO system. The object of the work was to produce a knowledge-base that could be used widely by medical schools whose particular faculties could regulate student access to it and modify or replace with locally-authored versions such parts of it as they wished.

Carnegie-Mellon suspects the computer of having a potential for educational usefulness that approximates, and might someday rival, that of the book, but it also suspects that it has a greater potential than the book to get in the way of education if used inappropriately or if access is difficult or use is perceived to be tedious or time-consuming.

The original implementation, which accumulated several thousands of hours of student use over a five-year period, provided for all of the following:

- Constructing author-specified outlines of information;
- Displaying this information in discrete units called frames;
- Accepting and displaying student comments and questions in context;
- Marking places in the text for future study;
- Linking learning objectives and references to specific text;
- A source of the preparation of hard copies of standard linear text;
- Segregating information (knowledge-base) from system (managing programs);
- Using a simple command language by knowledge-base authors;
- Flexibly accepting new programs to support authoring functions.

Experience with the original implementation coupled with such new developments as powerful personal computers and enhanced videodisc interfaces have led Dr. Thursh to undertake a reimplementation aimed at making the user interface "friendlier" to first-time users and making the overall structure of the system more apparent to users. Called KAMES (for Knowledge Access Management and Extension System), the newer implementation of the on-line pathology textbook, begun on a DEC VAX 11/780 minicomputer and recently adapted to run on a Cadmus 9000 series microcomputer, is intended to generalize its applicability from undergraduate studies to postgraduate and continuing professional education. To date, the redesign effort has yielded a system that is: 1) capable of supporting both systematic study of a large body of subject matter by beginning students and directed inquiries by more sophisticated learners, and 2) capable of running on increasingly smaller computers. A version that will run on an IBM PC-AT has performed student-oriented system operations in a manner comparable to that in which they are performed by versions that run on VAX and Cadmus computers, and a version that runs on the less-powerful PC-XT has successfully performed all tested operations, albeit with some degradation as compared with the larger machines. A version that will run on an upgraded Apple Macintosh personal computer is eventually expected.

Among the 1.8 Megabytes of machine-interpretable information that comprised the KAMES system in February of 1985 are some twenty thousand lines of text suitable for viewing by other academic pathologists. A related demonstration videodisc contains about twenty-five hundred color illustrations from the teaching collection of the Illinois College of Medicine at Urbana-Champaign and from the personal collection of Dr. Thursh.

Future development will be directed at imbuing the system with sophisticated capabilities—derived from applications of artificial intelligence—for automatically propogating changes throughout the knowledge-base, for controlling inadvertant redundancy within it, for automatically cross-referencing frames that are logical parts of more than one hierarchy, and for making English language access easier and more flexible. Ultimately, the system is expected to be able to take on the role of a collaborator in research by postulating relationships unnoticed by the content expert, and to evaluate the completeness of knowledge bases and ask content experts for missing information.

Underway is an effort the put the system in touch with established bib-

[3] Information about the work of Daniel Fivel was derived from Tucker, "Computers on Campus," 26-28.

[4] Information about the work of Donald Thursh was derived in part from Tucker, "Computers on Campus," 32-33, from Donald Thursh, Frank Mabry, and Allan Levy, "The Knowledge Access, Management, and Extension System in Pathology," *Proceedings of the AAMSI Congress, 1985*, ed. A. H. Levy and B. J. Williams, (American Association of Medical Systems and Informatics, 1985), 402-406, and from personal communication. All quotes are from Thursh, "The Knowledge Access, Management, and Extension System."

liographic databases, such as MEDLINE, in order to facilitate literature searches. This work is consistent with the overall direction of the system; according to Dr. Thursh:

> Our long-range vision for KAMES is a mini-library of biomedical science, "staffed" by a small but efficient expert system in lieu of a human librarian. It will include textbooks of anatomic and clinical pathology, basic biomedical science, and the major clinical specialties, and a user-directed abstracts service plus whatever available on-line journals are desired—all of which will be "aware" of each other's contents and able to access each other as readily as they access themselves. The library will also have an extensive audio-visual section that will be fully and automatically indexed through its textbooks and journals.

Besides students and teachers, interns, physicians, and medical researchers might be expected to use and augment the text of KAMES. Growing and changing thus, it will truly be a "body" of knowledge.

Choosing partners

The "marriages" alluded to earlier in this article occur when an institution undertakes to make the personal computer ubiquitous and to wire the campus so that each can, if it wants to, communicate with any other as well as with any of the institution's shared computing facilities. For so leviathan an undertaking an institution needs, not just a mate, but a very particular mate. Three of the most eligible have pledged their troths to one or more of several institutions that went a'courting.

Like Dartmouth College, Carnegie-Mellon University evolved an extensive network of timeshared computing. Third-ranked among private universities in total dollar volume of industrial research, Carnegie-Mellon—with a tradition of emphasizing maximum access to computing resources for students, researchers, and computer scientists—held a leadership position in computing as it entered the 1980s. But resources and leadership notwithstanding, Carnegie-Mellon faced the same stark reality that confronted so many other institutions—that to provide sufficient computing capability to every member of the University community under the timesharing model was becoming prohibitively expensive. Although Carnegie-Mellon, too, would embrace networked personal computers as the solution to its computing dilemma, it began by seeking what its President, Richard Cyert, described as "a broadly based view and a sense of perspective about where we want to go"[5].

Before focusing on hardware, Carnegie-Mellon assessed its existing and desired states. Working from the assumption that computing is fundamentally good for it, the University discovered that major attributes of an optimally operating timesharing system continue to have relevance, for example, enough terminals (workstations), generally-adequate response times, sufficient storage, and quick and convenient printing. Inasmuch as growth would inevitably have to accommodate a mix of large and medium-size computers required to support services with high-volume storage requirements, as well as terminals and stand-alone workstations for the bulk of local uses, extension and refinement of an underlying communication network and simplification of access to it were deemed essential. An information system of sufficient scope to index the profusion of computing resources available to the University community was also deemed necessary, as was access to appropriate databases and to relevant and well-conceived documentation and human consultation.

Carnegie-Mellon suspects the computer of having a potential for educational usefulness that approximates, and might someday rival, that of the book, but it also suspects that it has a greater potential than the book to get in the way of education if used inappropriately or if access is difficult or use is perceived to be tedious or time-consuming. The University regards many existing educational uses of the computer as demonstrated, including, among others: management of education, as in scheduling and grading; display of information in classrooms; application to writing, in general, and composition, in particular; numerical analysis in data-rich disciplines such as social science and computation-rich fields such as engineering; tutorial delivery in drill-and-practice domains, such as music and language training; simulation of all manner of complex systems.

Carnegie-Mellon's interpretation of "computer literacy", like that of the Stevens Institute of Technology, stresses fluency. Anticipating that the overwhelming majority of users of computing will be consumers, not writers, of programs, it focuses on promoting competence with available tools, such as electronic mail, word processing, simulation, and statistical packages, and computer-aided-design and database systems. Underlying these skills should be an appreciation for what constitutes the appropriate application of them, and underlying that, an elementary understanding of what a computer can and cannot do. The University regards student competence with institutional computing facilities, of which network access is a fundamental component, to be a matter of practical exigence.

Although it anticipates that the computer will have an increasingly profound effect on the nature of education, Carnegie-Mellon expects use to be diverse and extremely uneven and supports the primacy of the role of the teacher in determining how best to educate.

As the computer becomes more integral to the delivery of education, reliability of the institutional framework of computing resources becomes more crucial. Carnegie-Mellon contrasts the replaceability and interchangeability of conventional educational facilities—such as classrooms, books, pens, and paper—with the computer.

Although acknowledging that the personal computer's infiltration of academic life must be attended by questions of a social nature, Carnegie-Mellon suspects that the most significant and profound of these might not be anticipated. While it waits for them to emerge, the University will ponder questions whose broad apprehension renders them seemingly intuitive. Answers posited to many of these questions, like the Roman god Janus, face in two directions at once. Overreliance or overindulgence might be

[5] Information about Carnegie-Mellon University, including quoted material, was derived from Tucker, "Computers on Campus," 3-10.

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limiting; a readiness to adapt everything to the problem-solving methodologies of the computer could lead a student to allow personal skills and abilities to atrophy. Yet, as it becomes, like the telephone and television before it, an accoutrement of daily life, the computer, when used obsessively, might pose no more threat to an individual than those other household contrivances. Among other questions are those that are seemingly antithetical one to another. Some fear that computers might violate students' desirable or rightful privacy, intruding on already crowded living space and/or opening students, through their machines and the data thereby contributed to and withdrawn from "the network," to unrestrained scrutiny by faculty and university officials. Others worry that pervasiveness of the personal computer will lead to student isolation by reducing the need for, and denigrating the role of, direct interpersonal contact.

Having taken stock of itself and its mission, and taken under advisement such issues of implementation as could be identified, Carnegie-Mellon purposed to reshape its computing resource around a sophisticated telecommunications network capable of supporting easily initiated interconnections among and between the primary computing resource, distributed among the entire University community in the form of powerful workstations, and larger, centrally- or departmentally-administered computers. A comprehensive formal proposal sent to several major corporations in 1980 asked for:

> (a) funding for a software development center, (b) equipment and/or financial support to implement an advanced prototype environment at Carnegie-Mellon University, and (c) a commitment for a complementary development effort within the company.

Its interest piqued, IBM announced, in 1981, a six-month engagement during which it undertook a joint feasibility study with, and quartered a small staff at, Carnegie-Mellon. The two have since consummated the relationship and work toward the realization of the University's computing environment of the 1980s is progressing apace. In addition, Carnegie-Mellon has allied itself with some fifteen other universities in a consortium whose intended purpose is to promote the development of useful educational software and the sharing of networked personal computer applications.

Brown University, a liberal arts college in Rhode Island, has also entered into a compact with IBM[6].

Brown's computing background is comparable to those of other institutions that have sought liaisons with major corporations. It shares the dual tradition that has proved to be self-defeating at so many: providing as much computing resource as possible, and promoting the institution-wide access to, and use of, the resource that inevitably consume it. Like others that have attempted to make computing pervasive, Brown has faced the declining prospects for timesharing to meet, in an affordable way, the exploding demand that its computing policies has engendered.

Like Carnegie-Mellon, Brown University was possessed of an extensive telecommunications network when it began deliberating the future of computing on its campus. Dubbed BRUNET, Brown's broadband network, in 1982, consisted of some fourteen hundred ports in one hundred and thirty-five buildings which originated traffic variously related to energy management, security, television, and high-speed, terminal-to-mainframe timeshared computing. But unlike Carnegie-Mellon's efforts, which reflect that school's technical orientation, activity at Brown has achieved a utilization of computers across a broader range of academic disciplines. The School had already, for example, employed an innovative technique, based on a concept evolved by Theodor Nelson, in both poetry and energy management courses. Called "hypertext", the technique consists of related bodies of text joined by predefined links. As used in the poetry course, hypertext enabled students to call up simultaneously on a screen, with a couple of keystrokes, a stanza of poetry and attendant professorial critique. The work of another critic, cited in the latter, could additionally be called up, and personal comments of the student entered in and appropriately linked, with equal facility.

Like Carnegie-Mellon and Dartmouth, Brown saw in the networked workstation model a way to preserve the positive aspects of timesharing (primarily inter-user communication and access to centrally-supported services) while eliminating its negative characteristics (periodic exhaustion of the computer's capacity by increased demand). In addition, workstations can afford students capabilities, such as real-time graphics and animations, that are impractical to implement on timesharing computers. As early as 1982, Brown's Department of Computer Science had initiated an experiment in which students in introductory computer science courses were afforded access to a laboratory of sophisticated Apollo workstations on which to run locally-developed, graphics-based instructional software capable of animating the concepts it described.

Brown looked to IBM's substantial corporate resources for a large part of the funding and support that would be required to transform the workstation model into an institutional schema for providing educational computing. Among the attributes that Brown would bring to the partnership were: a liberal arts environment in which to explore the potential of networks of powerful workstations to further educational objectives; a demonstrated interest in making computing an intrinsic part of the educational experience of its students; and a pervasive communications network that attested to that interest.

Relationships between colleges and corporations are seldom monogamous. IBM is involved in at least three major partnerships and eighteen additional alliances through its Advanced Education Projects, while Brown University has acquired equipment with an aggregate value in excess of one million dollars from relationships with Apollo Computer and Apple Computer, and has secured a three-year, million and one-half dollar Annenberg/Corporation for Public Broadcasting grant to support educational software development.

Corporations and universities have

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[6] Information about Brown University was variously derived from Tucker, "Computers on Campus," 11-17, and from Norman Meyrowitz, *Networks of Scholar's Workstations: End-User Computing in a University Community, Preliminary Report* (Brown University, Institute for Research in Information and Scholarship, 1985), and Nicole Yankelovich et al., *The Sampler Companion*, (Brown University, Institute for Research in Information and Scholarship, 1985).

Corporations and universities have evolved variant patterns in their search for relationships. Corporation-initiated liaisons tend to be by invitation and hence somewhat exclusive, whereas universities are disposed to make overtures to several partners at once, but with the object of securing non-exclusive unions that will not preclude their search for other companions.

evolved variant patterns in their search for relationships. Corporation-initiated liaisons tend to be by invitation and hence somewhat exclusive, whereas universities are disposed to make overtures to several partners at once, but with the object of securing non-exclusive unions that will not preclude their search for other companions.

A considerable amount of the effort being expended at Brown is related to the development of a family of "scholars' workstations" and educational software to run on them. This activity has been centralized at Brown in the Institute for Research in Information and Scholarship (IRIS). IRIS is being fertilized by basic research carried on in the Department of Computer Science and its seeds carried throughout the University by the agent that has heretofore distributed timesharing computing to the Brown community, its Computing and Information Services organization.

IRIS has already propagated. A development effort carried out during the summer of 1984, in which faculty from several academic departments at Brown cooperated with IRIS staff, yielded a "sampler" of subject-specific applications programs with consistent interactive characteristics.

- A program that helps students to develop, and then tests, their knowledge of Middle Eastern geography is among the sampler programs currently being offered for evaluation by Brown faculty. Three modes of more-or-less conventional CAI-type interaction with the program are possible. A tutorial "presentation" mode will highlight, and display information associated with, each location identified on a map display occupying most of a workstation screen. In "query" mode, students are required to respond with the correctly spelled name of the location that constitutes the answer to a program-generated question, and then to "point" to the position of the location on the map display by means of a hand-held mouse. A "labelling" mode, intended for pre-exam use, calls for students to point to unlabelled locations on the map display in response to program-generated location names.

- A program that presents physics students with practice problems related to conservation of energy not only evaluates the correctness of their solutions, but also illustrates, by means of graphic displays, the physical events that would result from the solutions. A student, for example, having supplied from one to four requested parameter values related to the compression of a spring and the mass of a cart resting on top of it, can be provided with both the numerically-reported height to which the cart is propelled by the spring's release and a simple animated display "showing" the spring's release and the resulting vertical projection of the cart.

A functional calculator display at one side of the screen can be used to determine parameter values from formulae. "Wrong" answers provide clues that help students on subsequent iterations of a problem. It has been suggested that the simulation's "tell *and* show" mode of interaction might help students to build an intuition about the phenomena under consideration.

Although its problem set is presently limited by the time and skill required for development, the program, unlike a textbook, is capable of presenting alterations of each member, thereby expanding its repertoire somewhat. Because it considers the techniques embodied in this program to have sufficient educational potential to warrant generalization not only to biology, chemistry, engineering, psychology, and other sciences, but also to disciplines, such as agriculture and economics, that rely on real-world models, IRIS is endeavouring to find ways to simplify the creation of complex animations and simulations.

- A chronology of events associated with nuclear arms issues—including developments in nuclear weapons technology, significant arms control policies, agreements, and theories, highlights of U.S.-Soviet relations, public-opinion polls, and conjectures regarding potential psychological, social, and physical effects of a nuclear war—are presented to students as a timeline by a program developed jointly by IRIS and Brown's Department of Computer Science and Center for Foreign Policy Development. Associated with each event recorded on the timeline are supplementary materials, which include an annotated bibliography of books, articles, and journals, a glossary of terms and acronyms frequently employed in nuclear arms literature and debates, and a list of suggested research topics. The timeline itself integrates graphic displays and animated sequences with textual information.

Like the geography program described earlier, the nuclear arms issues program affords students several modes of interaction. Students can take a sequential trip on the timeline, visiting in chronological order, either every event on the timeline, if they select a comprehensive itinerary, or only events in a specified category, such as "technology" or "arms control", if they choose a selective one. Alternatively, it is possible for students to "browse" through the timeline in a random and non-sequential manner.

In addition to providing a means for obtaining quickly a concise overview of relevant subject matter, the nuclear arms issues program also enables students to locate essential background facts without resorting to extensive outside reading by conducting successively narrower searches via the timeline.

A common development vehicle is essential if educational programs are to be consistent and generalizable. Just as library patrons are not required to learn a new way of interacting with

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a book each time the library acquires a new one, so users of educational software should not be expected to learn a whole new way of interacting with each new piece of educational software. Brown has achieved the first part of its two-part goal for educational software—consistency. Students taught to use one of the programs from the IRIS "sampler" have been able to use all of the others without additional instruction. This has been achieved, in part, by creating all of the subject programs in the same software environment.

Called Intermedia, the environment in which the "sampler" programs were developed was adapted from, and incorporates components similar to, the Brown Algorithmic Simulator and Animator, or BALSA, which was designed and used by the Computer Science Department to write its sophisticated computer science teaching system. Both environments provide a window manager, menu package, and mouse interface.

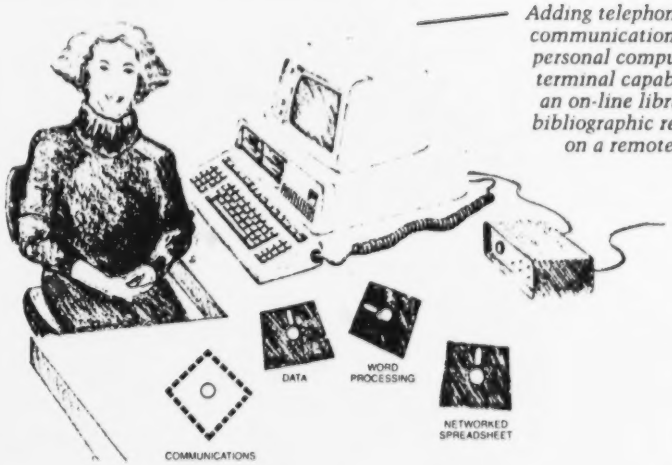
Future educational program development at Brown will emphasize its other targeted goal—generalizability. The Intermedia environment is expected to facilitate development of educational software that can be easily adapted from one course, or even discipline, to another by simply adding, changing, modifying, or eliminating text, graphic displays, animations, and/or associated references. Intermedia is planned as a total environment, in which instructors will be able to not only create and adapt educational software, but also do their daily work, such as word processing and graphics editing.

The "sampler" has given rise to proposals for additional program development in English, music, and cell biology, among other subjects.

A personal computer is a personal computer...

A personal computer can be just that, a personal computer. I can plug it in, insert word processing and data diskettes, and compose, revise, and format writing assignments in the quiet and comfort of my own room.

...is a computer terminal...



Adding telephone, modem, and communications software, my personal computer becomes a terminal capable of querying an on-line library catalog or bibliographic retrieval system on a remote computer.

With a goal of one workstation for every student, faculty, and staff member by the end of the decade, an estimated ten thousand machines, work toward the identification of a family of affordable workstations continues within IRIS. "Identifiable" is a key word, since it is not the goal of IRIS to create new hardware.

For the present, IRIS has settled on surrogate machines that either fall short of its workstation criteria or are too expensive to ultimately satisfy its volume requirements. Brown's requirements are for a machine that can provide:

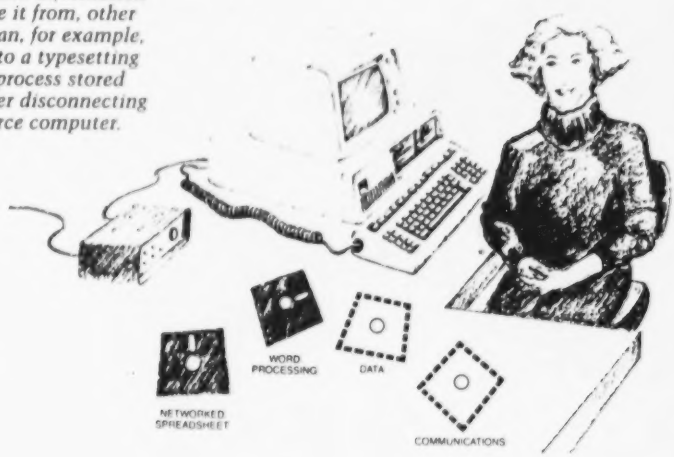
- power equivalent to what a user can obtain via a terminal to a mainframe;
- sufficient memory (at least one Megabyte) to support the graphics environment;
- a large bitmapped display (one thousand by one thousand pixels) capable of supporting full-page displays of text;
- a mouse-type user interface;
- sufficient local hard-disk capacity (twenty to forty Megabytes) to store book-length works;
- and hardware to interface it to the campus computing network.

A need is perceived for three levels of machine that take these requirements as a starting point:

- a low-end machine that is affordable by individual students and faculty members;
- a mid-range machine capable of supporting general teaching and research activities;
- and a high-end machine with an

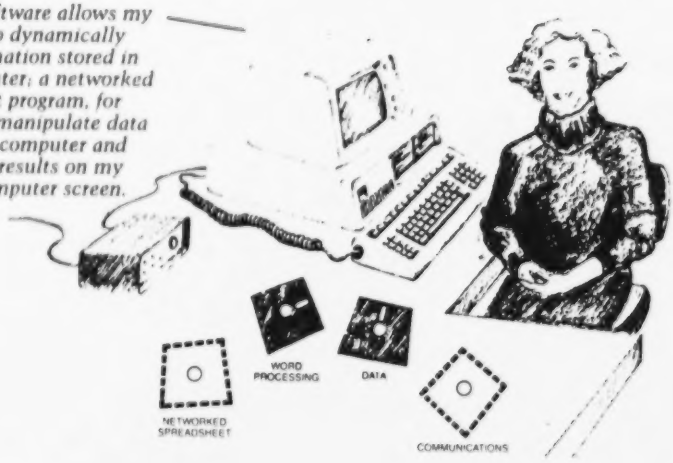
...is a distributed processor...

Unlike a terminal, my personal computer can send information to, and retrieve it from, other computers; it can, for example, send text files to a typesetting computer or process stored information after disconnecting from the source computer.



...is a networked workstation.

Networked software allows my computer to dynamically access information stored in another computer; a networked spreadsheet program, for example, can manipulate data in a remote computer and display the results on my personal computer screen.



advanced and extended set of capabilities that will support endeavours of greater complexity.

Although it fails to meet several of Brown's requirements, the Apple Macintosh was deemed the first affordable low-end machine to incorporate the desired graphics interface, employ a consistent mode of interaction across applications, and provide an operating environment that supports development of sophisticated applications. A refined IBM PC/AT, utilizing third party software to achieve consistency of user interface and an operating environment suitable for applications development, is considered a potential candidate for Brown's mid-range machine. Until a high-end machine affordable enough to be acquired in volume becomes available, Brown will continue to fill its needs for advanced function workstations with small numbers from Apollo and Sun.

An hour north of Brown, but on the same tack, the Massachusetts Institute of Technology (M.I.T.) has paired itself with both IBM and DEC in a five-year effort to create a cohesive computational environment incorporating some two thousand high-performance workstations (equivalent to what Brown views as medium- to high-end machines) and a pervasive communications network[7].

Because, like Carnegie-Mellon University, it expects that it will have to continue to accommodate computer equipment from a variety of manufacturers, M.I.T. has adopted a two-tiered networking scheme. To be promulgated through a network, data must conform to a specified format, or *protocol*. A number of manufacturers offer local area networks as products; clusters of a particular manufacturer's equipment are often most expeditiously interconnected using these products. A proliferation of such networks, which it considers inevitable, constitutes the lower tier of M.I.T.'s networking scheme. But because they frequently employ different protocols, local area networks from different manufacturers can seldom communicate with one another directly. In order to realize a network that is truly pervasive, M.I.T. must provide a means for interconnecting dissimilar local area networks. This it will achieve through the upper tier of its scheme, a common spine, or backbone network, provided with a single established protocol and a varied and changeable set of *gateways* (programs that enable communications traffic to "change clothes", exchanging one network's protocol for that of another).

Notwithstanding the considerable financial commitment associated with the implementation of the technical elements of its project, the Massachusetts Institute of Technology, like other institutions similarly engaged, reserves its greatest concern for the educational ramifications of the project. Central to that concern is the development of software to be used in the educational process.

An internal grant program, together with a substantial Annenberg/Corporation for Public Broadcasting grant, is providing the principal source of funding for educational software development. More than fifty individual development projects, as varied as

[7] Information about the Massachusetts Institute of Technology was variously derived from Tucker, "Computers on Campus," 17-22, and from *Project Athena: Faculty/Student Projects*, (Massachusetts Institute of Technology, Project Athena, 1985).

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the schools and departments that have proposed them, are currently underway throughout M.I.T. A fraction of these are accorded a few lines of description each below.

■ The conceptual basis for an "electronic journal," the software for which is being developed by the School of Architecture and Planning, is the artist/engineer's journal as used by Leonardo da Vinci. The electronic journal is intended to serve students in much the same way that personal journals have served them—as a place to collect and manipulate clipped, and perhaps annotated, passages and pictures, class and personal notes, and sketches that can variously provide inspiration and spur creativity. In electronic form, a journal's content can be shared, in toto or selectively, as immediately as it is compiled. It can be extended beyond what one can write or paste into a notebook to include, for example, photographic prints and slides and videotape frames; and it is much more amenable to editing, and to interleaving with materials drawn from the journals of others, than an equivalent paper journal. There is hardly an academic discipline in which such a journal would not have utility.

■ The Department of Aeronautics and Astronautics in M.I.T.'s School of Engineering is attempting to put an acknowledged strength of the computer, simulation, to a particularly ingenious use. In the evolution of computers, as in that of homo sapiens, there were divergent tracks. The supremacy of the digital over the analog computer resulted from a combination of technological know-how and economics; computers that dealt with discrete, rather than continuous, quantities proved to be easier to design, more economical to manufacture, and, for the vast majority of tasks to which they are applied, entirely appropriate. Yet, because the continuous nature of real-world processes is mimicked in its very design, the analog computer is an ideal tool for modelling dynamic systems such as rocket boosters. The object of the Aeronautics and Astronautics department's project is the creation of a "glass analog computer," an analog computer built not of real-world components, but rather created in the central processor of a digital computer. A digital computer that can be made to behave like an analog one could serve as a sophisticated "electronic blackboard" in lectures. This work forms the base of a broader effort to develop a teaching system that will incorporate a dynamic world model, and employ artificial intelligence to provide an associated expert system and expert tutor. The developers anticipate that realization of their goals could lead to a restructuring of the way in which dynamics is taught.

The handful of large-scale, multi-million dollar projects being fostered by college-corporation-foundation partnerships have much in common, but they constitute only a brief, if bold, stroke in a pattern with many variations.

■ A project undertaken by the Department of Chemical Engineering, also in the School of Engineering, is directed at filling an instructional void. Physical models employed to help students visualize molecular structures, besides being often unwieldy and difficult to show adequately to an entire class, have no utility for demonstrating inter- and intra-molecular interactions. The Chemical Engineering department's effort is directed at producing a graphics program that, together with a collection of structural data for simple molecules, will enable students to display and effect a variety of manipulations to molecular structures.

■ Engineering students face a similar problem in trying to visualize electromagnetic fields. If a Department of Electrical Engineering and Computer Science project realizes its full potential, it will not only provide a substitute for the time-consuming practice of trying to draw, in two dimensions, complex three-dimensional fields, but also simplify the calculation of field quantities. Simplification of calculations is to be achieved with the aid of a symbolic computer language, visual presentation with computer-generated graphics.

As noted earlier, M.I.T.'s projects are multitudinous. At least two involve videodisc technology: in mechanical engineering, to enable entering students with varied backgrounds to fill in, outside of class time, gaps in their experience; and in biology, to enhance the presentation of vast amounts of pictorial material and data that is only amenable to presentation in time-lapse microphotography. Introductory courses in several disciplines have been redesigned to incorporate relevant computer experience. A number of projects have added new numbers to the listings of courses in M.I.T.'s catalog.

And out of these unions...?

Though representative, activities and concerns related in this article are, of necessity, selective. The handful of large-scale, multi-million dollar projects being fostered by college-corporation-foundation partnerships have much in common, but they constitute only a brief, if bold, stroke in a pattern with many variations.

For instance, all of the major efforts described above are being built on the model of distributed networks of intelligent workstations, or personal computers. Far from being dead, or even obsolete, timesharing remains an acknowledged component of this model, and even, for some institutions, a viable alternative to it. In an article[8] in the *New York Times* for May, 13, 1984, Education Editor Edward B. Fiske cites the example of Union College in Lincoln, Nebraska, which has wired, and installed timesharing terminals in, all four hundred and ten of its dormitory rooms. Timeshared computing will be provided to the school's liberal arts students by a Hewlett-Packard mainframe computer. Union President, Dean Hubbard, opines that his school is "probably at the top edge of a size of institution that could do this."

[8] "Computers in the Groves of Academe," *New York Times*, 13 May 1984.

As the rush to offer the "computer advantage" proceeds apace, colleges and universities, large and small, are casting about for ways to fund hardware and foster the development of useful software.

Even those institutions that have garnered substantial infusions of capital from major computer manufacturers, recognizing that that reservoir will not long persist, and concerned about being perceived to be diverting monies raised to meet other institutional obligations, such as faculty salaries, building construction and maintenance, and library needs, have concomitantly launched fund-raising drives the proceeds of which are targeted for continued support of their respective projects. For the rest, fund-raising can be supplemented with grant proposals, compromises in the operating budget, increases in already high tuitions, and such less grand deals as can be struck with equipment manufacturers. In what is increasingly becoming a two-tiered arrangement, institutions are assuming responsibility for providing the network component and some set of central support services and are encouraging, or insisting, that students supply the complementary computing component. Some worry that a stratification of computer "haves" and "have-nots" among educational institutions might be reflected in a corresponding stratification among college graduates.

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One might conclude, from the paucity of really good educational software presently available, that for all of the fanfare associated with it the "computer advantage" could come to naught. Classical "computer-aided instruction," or CAI, after all, has over its twenty-year history had little effect upon education. Of the innovative software described earlier in this article, some is in use, but much more of it is "under development." Some of the latter will never be completed or, being completed, will prove ineffectual. Yet, some might prove so successful as to effect radical changes in the mode of presentation, and even the content, of a given subject area.

In his earlier referenced *Times* article, Mr. Fiske, reviewing the ambitious computing strategies of a number of institutions of higher learning and the stakes, as well as the expectations, that accrue to them, remarked that "it may be significant that Harvard University has done little more than appoint some task forces to study the issue." That Harvard has since, though its footfalls have hardly been heard, taken steps toward the integration of personal computers into its academic curricula was reflected in the observation of its President, Derek Bok, in a talk delivered prior to publication of the *Annual Report of the President to the Board of Overseers of Harvard College*, that "even at stodgy old Harvard things are beginning to happen." Mr. Bok went on to enumerate uses of personal computers in several of Harvard's professional schools, including the Harvard Medical School, the Harvard Law School, and the Harvard Graduate School of Business Administration. (Uses by the latter, and by academic departments and the administration of the Faculty of Arts and Sciences, are described in accompanying articles.) The full-text of the President's assessment of the promise and the reality of technological innovation for education was published in both the *Harvard University Gazette* for April 19, 1985 and in the May-June, 1985 issue of *Harvard Magazine*. His prefatory talk was one of several on the subject of education and technology delivered at Harvard during the second semester of 1985.

A series of speakers invited by the Harvard Graduate School of Education, which is a member of, and provides space for, the Educational Technology Center, a National Institute of Education-funded group engaged in research directed at identifying means to improve standards and performance in mathematics, science, and computer science education, contributed greatly to a sense of perspective on the level of attainment thus far achieved in advanced instructional computing. In a talk loosely titled "Why teach programming?," Elliot Soloway, a computer scientist at Yale University, related results of research conducted at his institution into how computers might shed some light on people and how they learn.

Dr. Soloway's inquiry into the nature of computer programming has led him to conclude that it consists primarily in learning to construct explanations and invent mechanisms, activities that correspond roughly to the setting of goals, and implementing of plans to achieve them, that people engage in continually. If, like the latter, the fundamental skills taught in computer programming are generic in nature, then perhaps, Dr. Soloway posits, they are transferable.

In fact, the focus of much of Dr. Soloway's research has been to determine whether cognitive skills learned in programming courses will transfer to other problem-solving disciplines, whether programming might be, as some suggest, the "new Latin", which, "to be able to learn is to be able to learn anything." Having found that even among engineering students, presentations of simple algebraic expressions, whether in words or pictures, elicit a surprisingly high percentage of incorrect solutions, Dr. Soloway endeavoured to determine whether inculcating in a group of such students the semantics of programming, which tend to be highly descriptive and procedural, might reduce the degree of ambiguity that seemed to account for their errors. In theory, the students would treat the expressions as equations to be solved in a program, regard their solutions as commandments to act, apply the appropriate functions, and derive correct solutions, much as if they were writing code in a programming language to act upon an instruction, call an appropri-

ate subroutine, and print out an answer. Though rigorously organized, and incorporating pre- and post-testing of the participants, this attempt to find transfer from the learning of computer programming to the learning of algebra was inconclusive in all respects but one; it hinted at gender differences. Undaunted, Dr. Soloway intends to repeat the experiment, with a different sample, in a different school.

Identification of appropriate models for academia, and a burgeoning market for training in industry and the military, will probably spur development of educational software, but a thorn under the saddle that could make the ride bumpy is the issue of ownership.

In another talk, a member of the faculty of psychology at the University of Pittsburgh and past director of Harvard University's Learning and Development Center, Lauren Resnick, observing that there is empirical evidence that weaker readers will be slower to recognize individual words, described an experiment in which computer software was used to drill students on word recognition with the object of improving overall reading abilities. Although the experiment failed to demonstrate improvements beyond speed of word recognition, later experiments with game-style programs that keyed on spaces between words showed some evidence of transfer and hinted at the potential efficacy of computer software in remedial reading applications. Later laboratory experiments achieved transfer up to the sentence, but not the paragraph, level posing questions as to what is special about this juncture.

Researchers inquiring into how children invent rules are tapping into work in artificial intelligence that attempts to understand why particular courses of action are followed. Like computer programs, the rules children invent frequently have bugs; there is a great deal of interest in why this is so, and in how buggy rules are debugged. Although conceptual (theory-forming) and procedural (rule-making) processes are suggested, where one begins and the other ends, and how the two interact, is not at all clear. Dr. Resnick described an experiment that attempted to gain insight into these phenomena by yoking two representations of a borrowing problem such that a solution carried out in one resulted in the presentation of the corresponding solution in the other. Children who solved the problem as represented with blocks saw a corresponding change in a numeric representation. Only one-half to one-third of the children who used the sophisticated combination of hardware and software that delivered this instruction showed evidence of acquiring the subject principles, and of these, only half were able to make the transfer of the acquired principles to the correction of previously-held buggy rules. The idea that providing children with graphics tools that enable them to perceive analogies between multiple representations of a single quantity will lead to the development of higher level concepts seems plausible enough, but the results of experiments conducted to date do not seem to support the hypothesis.

Much of the research described by Dr. Resnick shows a dichotomy between rule-development and theory-formation. Well-designed computer software has demonstrated some utility for fostering the former, but little potential, so far, for effecting the latter.

Parent-child reading activities, Dr. Resnick explained, exemplify a scaffolding type of learning experience in which a child takes command, a little at a time, of an object of learning that is present in its entirety from the outset; at first, the parent does most of the reading, the child little, but over time the roles reverse. Because it requires one-on-one or one-on-a-small group contact, this paradigm is usually not feasible in school settings. A computer, Dr. Resnick observed, could deliver individualized reading instruction by allowing a child to read from a textual display those parts with which he or she is familiar, and reading for the child, in a sufficiently sophisticated, synthesized voice, unfamiliar parts identified by the child with a light pen or some such device.

Most of the software referenced by Dr. Resnick was a long time in development and much of it runs on what are currently fifty-thousand dollar machines. Machines of equivalent capability that are affordable enough for classroom use, she suggested, will probably be available in five years, a projection that Harvard President Derek Bok seems to have intuited in the opening remarks of his earlier referenced talk in which he observed that the mention of technology always calls up for him the hum of people working on things still about five years away.

Another invitee of the Graduate of School of Education last semester, Paul Evans, of IBM's Educational Systems Planning group in Boca Raton, Florida, suggested that educational software is still in an early stage of evolution, that it is just making the transition from the teaching-machine stage that has predominated since the 1960s, in which the machine is in control, to a learning machine stage in which control is shifting gradually to the learner. Mutations begun in the mid-1970s that could lead to a still higher evolutionary stage, in which the machine might function as concept builder, continue. Products of artificial intelligence—expert analysis systems that can seek out information and explain their reasoning—are a key component in the development of machines that can serve as true partners in learning.

According to Mr. Evans, the market for educational software has, to date, proved less lucrative than anticipated. A leading purveyor of educational software products, he noted, went from a nine million dollar business one year to near-bankruptcy the next. That most contemporary educational software is based on the old CAI paradigm he attributed to the failure of research to provide technical assessment models. Presumably, some, at least, of the network, workstation, and software development projects in which colleges and universities, both individually and in partnership with major corporations, are engaged will yield models for appropriate uses of technology in education.

Derek Bok, in the conclusion of his *Annual Report*, stresses the importance for university administrations to persuade their best teachers, with funds and technical assistance as well as with equipment, to devote their energies to the design and development of imaginative educational software. The best teachers, he observes, will "have thought most about how students learn and will attract the widest interest and command the greatest respect for the work they do in using technology in their courses." Nor does he neglect the complementary component of software development—evaluation—observing that, "with ingenuity...and a modest use of funds, a determined administration may be able to evaluate the new technology and thus learn to use it with discrimination."

Commercial software is protected by copyright law; hence, copying it without permission is illegal. That illicit copying is rampant, nonetheless, deprives vendors of their due and lowers the ethical standards of those who indulge in the illegal giving and taking.

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Software distribution is much simpler under the timesharing model; though it might be expensive, one (or perhaps two, if a university operates a second processor) package can serve an entire user population. Use of the software is usually provided "free", the computing service organization billing, instead, for such things as connect time, processing cycles, and consumables (magnetic tapes, paper, etc.). Bills are typically paid by a department or an office. Students are seldom required to do more than qualify, usually by virtue of being enrolled in an appropriate course, for a computer account. When the processor is no longer a large, shared, centrally-owned machine, but myriad smaller, individually-owned ones, the number of individual copies of each piece of software required for a given population to share a particular computing experience is greatly increased. In an instructional environment, in which students might have occasion to use a number of different software packages, some of them for only a short time and then never again, the cost of obtaining or providing enough copies for an entire class can be prohibitive if prices are high. Often they are.

The principal sources of commercial software products are so-called "software houses", whose prices, and protection schemes for preventing illicit reproduction and distribution, reflect high overhead and promotional expenses and a need to realize rapid profit growth; and computer manufacturers, which might price software somewhat more reasonably if only because their primary product is computer systems. Traditional book publishers, which see software publishing as an important part of their long-term strategies, are just beginning to exert an influence on the market.

Free of copyright restrictions is a wealth of software, much of it developed by universities or under government contract, which is in the public domain. Such software, besides being often difficult to identify and locate, is seldom of the quality of good commercial software, usually proliferates in a multiplicity of versions, and is often documented, if at all, only perfunctorily. Nevertheless, some universities have expended considerable effort to develop software internally, or to adapt public domain software, for applications that already exist as commercial products because the latter are deemed prohibitively expensive in the quantities required and the institution wishes to skirt the issue of illegal copying. The interests of all concerned would be better served if such perceived needs for redundant development were eliminated allowing universities to apply their efforts to the creation of innovative and novel applications, some of which might later serve as prototypes or models for new commercial products.

William Arms, while Vice Provost for Computing and Planning at Dartmouth College, summarized in a report prepared for the Interuniversity Communications Council, Incorporated (EDUCOM) of Princeton, New Jersey, issues related to software licensing for personal computers and types of agreements by means of which commercial software can be made affordable to educational users. Included in his report were:

- agreements for bulk purchase with discounts, whereby a university might buy in quantity from the manufacturer standard copies of software at list price per copy less some (usually significant) discount;
- agreements to buy copies for all computers, by which a university might agree, in exchange for a low price, to buy a copy of a manufacturer's software product for every computer that it distributes (a useful arrangement for such utilitarian software as word processing packages);
- campus licenses, a type of agreement preferred by many universities, in which individual copies of a product can be purchased at a low, marginal cost following an up-front payment (usually of several thousand dollars) to the supplier by the institution;
- agreements whereby an institution, in exchange for a low price, assumes responsibility for duplicating and distributing software and manuals, (sometimes employed in the case of preliminary versions of packages accompanied only by manuscripts of manuals);
- student packages, which exchange a lower price for lower product functionality, different packaging, a partial set of manuals, of some combination of these elements.

Dr. Arms' report suggests that maior software packages and large textbooks are comparable in the amount of effort required to produce, and the cost of distributing, them and that the pricing of software will follow the pattern of textbooks, with prices kept relatively low by competition among several good products for every important market niche. He notes the availability of good compilers and word processing packages for about fifty dollars and predicts similar pricing for spreadsheet, database, and statistical packages in the near term. Some products, he allows, will remain expensive because of inherent complexity or application specificity, or simply because the market for them is not price sensitive.

Overall, the effect of competition and widespread adoption of creative licensing agreements should be to reduce the incentive for making unlicensed copies of commercial software products. Dr. Arms suggests in his report that, just as few people will take the trouble to photocopy a two hundred-page book, even though to do so would be much cheaper than to buy it, when software packages consisting of a disk, a back-up disk, and a couple of manuals can be purchased for less than fifty dollars, a similar disinclination will obtain.

Paul Evans, of IBM, expects that the evolution of easy-to-use, state and national telecommunications networks will foster a return to the time-sharing model of distribution for much of educational software. State departments of education, he posited, might purchase packages that would, in effect, become state property, like state vehicles, with equivalent penalties for unauthorized use. Network access to such packages might be metered, like a utility, and the various users billed, according to their respective amounts of use, by the departments of education. When the criteria for selecting equipment becomes network compatibility, and the network is the principal provider of software, the tendency for hodge-podges of limited-application machines to accumulate and rapidly become obsolete might be reduced, and some balance and consistency introduced to the use of computers in the educational mission state-wide.

What the pedagogical value of commercial educational software will be, however affordable or available it might be made, remains to be seen. Certainly, there is, amongst the panoply of software currently available to students, much that can reduce what has been called the "drudge work" of the educational process. Word processing packages, on-line library catalogs, and bibliographic search services can save students, faculty, and researchers a great deal of time and effort that they can presumably redirect to being more creative and prolific.

With our ability to make rote much of what we do in order to concentrate on other things even as we do it, we might ponder, as we compose our litany to the computer (preserver from mental drudgery, boon intellectual companion, etc.), what the elimination of earlier forms of drudgery has yielded. The scribe's pen freed philosophers and poets from the need to exercise their vocal chords in the delivery of long orations and the recantation of lengthy epics; the printing press eliminated the need for scribes to copy, in a flowing hand, and with successive adornments and embellishments of both copy and content, the written works that earlier eliminated the need for philosophers and poets to exercise their vocal chords in the delivery of long orations and recantation of lengthy epics. Might not there be some loss in our concomitant freedom from truly great orators and beautifully inscribed documents?

A recurring tendency to posit lofty intellectual ends from the elimination of tedious labor by mechanized means was expressed in an extreme form by Oscar Wilde in *The Soul of Man Under Socialism:*

> There is no doubt at all that this is the future of machinery: and just as trees grow while the country gentleman is asleep, so while humanity will be amusing itself or enjoying cultivated leisure—which, and not labor, is the aim of man—or making beautiful things or reading beautiful things or simply contemplating the world with admiration and delight, machinery will be doing all the necessary and unpleasant work.

Education is, at best, a hopeful process. It attempts to inculcate in many and diverse individuals, through somewhat fewer diverse individuals, some heightened sense of the world they must inhabit and some basic set of tools by which they might further their comprehension of that world in order that their occupancy of it might be relatively comfortable and productive. One need not look widely to see how far short it falls of achieving its ends. Whatever help it can get should be welcomed.

The potential of the computer for education may be greater outside of the classroom than in it. The overwhelming use of contemporary computers on college and university campuses takes place in dormitory rooms and in "common areas" in which shareable equipment is provided. Some correspondence schools are beginning to distribute courseware via computer and novel, profit-making enterprises are relying on computers to deliver teaching services through "one-room electronic schoolhouses" already established in a handful of retail malls and office buildings. Computers have been appropriated, too, by a growing number of parents who are choosing the alternative of educating their children at home.

Notwithstanding its promise, the computer should not be embraced as *the* enhancer of education to the exclusion of other, traditional and demonstrated, abettors of the process. Field-study, work-study, and foreign-exchange programs can provide inva-

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luable experiences that can be realized in no other way. Academic competitions—"mental decathlons" comprising written tests, interviews, speeches, and aural quizzes—are gaining in popularity, generating enthusiasm among parents as well as students, and garnering publicity for participating schools. Several such competitions have become national within the last few years.

As for the computer, how it can serve education is a question that can have many, and varied, answers. Some have already been supplied by students, some by institutions of higher learning. Many more are being posited by researchers.

Israel Scheffler, Professor of Education and Philosophy at Harvard, in another talk invited by the Harvard Graduate School of Education, spoke of, among other things, computers and hammers. Of the latter, he said that the uses that can be made of them are not limited by the implement's stereotypic application to the driving of nails. Of a certainty, there are things that a hammer cannot do, he conceded, such as serving as a soup ladle, but there are other things, such as serving as a doorstop, a bookend, or a paperweight for which it is suited, albeit not by design. "Its suitability," he explains, "for such non-conventional uses is neither guaranteed nor precluded by its stereotype but must be independently established for each case." So, too, for the computer.

On Christmas Day last year, the room containing the Christmas tree in the Dartmouth home of William Arms resembled such rooms throughout the country, littered with the wrapping paper from opened gifts. By tradition, the Armses compile a list of presents, identifying, from the labels and tags they carry, the giver and receiver of each, and noting for which thank-you letters are in order. At the suggestion of their young daughter, the Armses compiled last Christmas's list with the aid of spreadsheet software running on their personal computer. Lo, they encountered, that year, an untagged gift. Setting it aside until all of the other gifts were opened, then sorting the spreadsheet list, the family was able to readily identify which of its number had not yet opened a gift from which relative. Not what one would think of as a spreadsheet application, perhaps, but such are the nonconventional uses of personal computers. *J.S.*

Acknowledgements

The editor's indebtedness for resources and guidance extends beyond the citations in the text and footnotes of this issue's feature. For their valuable insights and careful review of the evolving piece, the editor is especially grateful to William Arms, Vice President for Computing and Information Services at Carnegie-Mellon University, Richard Schofield, Director of Academic Computing at Wellesley College, and Ronald Orcutt, Division Manager of Administration and Planning for Harvard University's Office for Information Technology. Observations of faculty and administrators interviewed in connection with, and individually acknowledged in, this issue's co-features on the Harvard Faculty of Arts and Sciences and Graduate School of Business Administration had relevance for this article as well. Printed matter to which the editor is indebted includes the Education section of the *New York Times* for 14 April 1985 for a practical survey of education and its practices and Harvard President Derek Bok's *Annual Report to the Board of Overseers of Harvard College* for a reasoned assessment of the relevance of computing technology for education. Also helpful were various issues of EDUCOM's *Bulletin* and *Computer Literacy Newsletter*, and undoubtedly other sources and persons whose identities the editor has lost over the course of the protracted assembly of this issue, but to which and whom he is nonetheless grateful. *J.S.*

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